

Impacts of Using Sisal Fiber with Mineral Filler on DBM

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ABSTRACT: In developing countries like India, the major source of power generation is primarily coal based thermal power generation plants. The primary waste from the coal based thermal plants is in the form of bottom ash and fly ash. This present study deals with the preparation of specimens of densely graded bitumen mixes by the use of naturally occurring coarse aggregates, fly ash in the form of mineral filler containing natural sisal fibers and bottom ash in the form of fine aggregates. The ratio of these aggregates and additives is being considered on the basis of MORTH Specifications (2013) with maximum grain size or nominal size of the grain as 40 mm. The mix is strengthened by the use of sisal fibers having slow setting emulsions (SS-1). The variable percentage of the fibers lies may be taken between 0 to 1 % having variations of 0.25 % each times. The different length of fibers is taken as 20 mm, 15 mm, 10 mm and 5 mm. During the initial stage of the experimental analysis, two types of bitumen (VG-10 and VG-30) are used for the preparation of samples. Out of these, the bitumen grade VG-30 turns to provide the better initial test results. The detailed analysis of Marshall tests helps to calculate the Marshall characteristics, optimum content of binder and fiber which includes the most appropriate length of fiber also.

Keywords: DBM, Sisal Fiber, Slow Setting Emulsions, Bottom Ash.

I. INTRODUCTION

The roadways including pavements are considered to be the backbone of the country on which the growth as well as upswing depends. Usually, all the countries consist of the sequence of the various programs for the construction of the new roads or the reconstruction of the existing roads, etc. Both the types of pavements i.e. rigid as well as flexible require the huge investment for their construction to attain the desired level of performance such as smoothness in quality and

durability. In the developing countries like India, the Government considers the roadways as the prime assets for their income which results into the investment of huge capital for their maintenance and construction. To fulfill all the requirements along with its reliable performance, an engineered survey and study is done. There are two major factors for flexible pavement which are found to affect the performance of the pavement namely, design mix and design of pavement. This present study deals with the engineering characteristics and behavior of bitumen mixes which are formed by some non-conventional materials.

1.1 BITUMINOUS MIX DESIGN

The bituminous design mix is the combination of stone chips having gradations between the nominal highest size of aggregates and finer fractions lesser than 75 microns along with some quantity of bitumen. It should be mixed and produced such that it might be compacted sufficiently with smaller size of voids and constitute to produce its destructive and elastic characteristics. The main objective this design mix is to calculate the adequate ratio of bitumen and fractions of aggregate to form an effective mix which has to be essentially durable, economical and reliable.

II. OBJECTIVES OF RESEARCH WORK

The compelling scope of this present research is to utilize the coal ashes in the form of fine material for HMA design mix which leads to produce some good quality roads of some smooth surface quality. These roads can resist any future environmental impacts and are found to be acclaimed on commercial scale. This comprehensive research study has been performed on Dense graded bituminous macadam (DBM) which focuses on the following outcomes:

[1] To study the various Marshall Properties of

- bituminous mixes over DBM by using the coal ashes and sisal/natural fibers both.
- [2] To study the various Marshall Properties of bituminous mixes over DBM by the use of sisal fiber but not coal ashes.
 - [3] To analyze the performance based characteristics of the bitumen mixes under the subsequent susceptibility of moisture along with and without use of natural fibers and coal ashes.

III. MATERIALS USED IN THE STUDY

For this study, there are various materials that have been used which are as follows:

- 1. Chips of Stones in the form of Coarse Aggregates
- 2. Bottom ash in the form of fine aggregates
- 3. Fly Ash in the form of mineral filler

- 4. Bitumen Binder VG-30
- 5. Sisal Fiber in the form of natural additive
- 6. SS-1 emulsion in the form of fiber coating agent

3.1 AGGREGATES

The coarse aggregates consist of chips of stones, purchased from the local crusher and classified as per their sizes by the use of different sieves. For this present study, the gradations of size of aggregates are taken in the range of 26.5 to 0.3mm. The fly ash and bottom ashes are taken as 5 % and 9 % by weight respectively for the fractions of mineral filler and fine aggregates. The fly ashes as well bottom ashes have been procured from the Khedar Thermal Power Plant. The primary characteristics of fine aggregates and coarse aggregates are tabulated in the Table 1.

Table 1: Primary Characteristics of Fine Aggregates and Coarse Aggregates [IS: 2386 (IV)]

Property	Test Result	
	Natural Aggregate	Bottom ash
Aggregate impact value	13.9 %	-
Aggregate crushing value	13.4 %	-
Los Angles Abrasion test	18.2 %	-
Soundness test (five cycle in sodium sulphate)	3%	8.3%
Flakiness index	11.8 %	-
Elongation index	12.7 %	-
Water absorption	0.138 %	10.78
Specific gravity	2.69	2.02

3.2 BITUMEN

The viscosity grade (VG) of bitumen is taken as VG – 30 for this study. Primarily, two grades of bitumen are taken namely VG – 10 and VG – 30 which are used to determine the Marshall properties of mix considered. The VG – 30 bitumen

in the form of binder has found to provide the better values of all concerned Marshall Characteristics when made from fly ashes, bottom ashes and emulsions coating with fibers. According to I.S. specifications, the physical properties obtained from the test of VG – 30 are given in Table 3.2.

Table 3.2: Physical Properties of Binder

Physical Characteristics	Test Result
Penetration at 25°C per 100 g per 5 sec, 0.001 cm	4.8
Softening Point	47.2 °C
Specific gravity (27°C)	1.02
Absolute viscosity at 160°C, Centi Poise	203

3.3 ADDITIVES AS SISAL FIBERS

The modifiers play a crucial in the performance of bituminous mix design. The actual fiber in the form of Sisal Fiber has been taken from the local market and used as modifier. These are used in the DBM mix in order to improve its engineering characteristics. This research work considers the sisal fibers coated with the emulsion

of slow setting nature (SS – 1), stored at temperature of about $110^{\circ} \pm 5^{\circ}$ C for at least one day. Sisal fibers are the soft-yellow coloured fibers formed by cellulose. These are found to be recyclable, durable and anti - static in nature. All the mechanical and chemical characteristics of the fibers are shown in table 3.3.

Table 3.3: Chemical Composition and Mechanical Characteristics of Sisal Fiber

Chemical Composition	
Composition	Test result
Cellulose, %	65
Hemicellulose, %	12
Lignin, %	9.9
Waxes, %	2
Mechanical Characteristics	
Property	Test result
Density, in g/cc	1.51
Tensile strength, in MPa	510-640
Young's modulus, in MPa	9.5-2.0
Elongation at break, in %	2.0-2.5

3.4 EMULSION (SS – 1)

The emulsion SS – 1 is the anionic bituminous based emulsion, containing slow rate of settlement. It is used to control dust, tack coating, sealing of fog as well as mix having fine gradations. These are the emulsions that are diluted with water and form a mixture with the aggregates as well as mineral fillers. The temperature of the pavements during construction is kept to be high so that the full curing condition to the emulsion is to

be maintained. In the SS – 1 emulsions, the percentage residual content is observed to be 71.68 % per 100 ml of emulsion by using the method of residue evaporation as per I.S. 8887 (2004).

3.5 FRAMEWORK

According to specifications from the Marshall procedure defined in ASTM-D-6927 (2015), all the constituents of the mixes like filler, fine aggregates, coarse aggregates, fiber and VG –

30 bitumen are mixed thoroughly as per the specifications. Before the preparations of the specimens, the coating of fibers is done with emulsion SS – 1 and kept at controlled temperature conditions of around 1100° C for 24 hours. This condition mainly helps the fibers to sustain a proper coating around it and the extra amount of the bitumen to be drained out. The different specified lengths of fibers for the test are kept as 20 mm, 15 mm, 10 mm and 5 mm respectively. The heating of aggregates and bitumen takes place in the temperature range of about 1550° - 1600° C. It is interesting to note that the temperature of the aggregates should be around 100° C above the temperature of the binders. The desired amount of the VG – 30 bitumen and fibers having emulsion layer are added to pre-heated aggregates and completely mixed.

The amount of binder that has to be added to the mix is calculated by the difference between mass of the binder designed and the mass of the fibers having emulsion coating. A manual mixing is necessary until the mix becomes uniformly coloured and consistent. The time required for mixing lies between 2 to 5 minutes with mixing temperature in the range of 150° to 160° C. This uniform mixture is poured to the Marshall mould and should be well compacted with the help of Humboldt Automatic Marshall Rammer. There are 75 numbers of drops to be provided over each side of the mould. The samples are then kept for 24 to 48 hours for their proper cooling to the room temperature of 25° ± 2° C (refer to fig. 4.6).

During the experiment, the measurement to the resistance against deformations caused to the specimen of the DBM mix is done. The rate of deformations for the specimen is kept at 5 cm per minute. There are two major characteristics of the Marshall method of the design mix, which are as follows:

- a) Flow Value and Stability Value
- b) Analysis of Voids

The maximum value of resistance offered by the sample of the bituminous mix at 60° C standard temperature is termed as Marshall Stability. Moreover, when the deformations of sample reach its maximum value, the flow value is noted down. The Marshall analysis of voids is always carried prior to the stability test. During this analysis, mass specific gravity, voids present in mineral aggregates, air voids, Marshall Quotient are also determined.

IV. RESULT AND ANALYSIS

Based on the study conducted by Das A. et al. (2010), all the Marshall properties of

materials/specimens are defined and the various relationships and formulas used for the calculations are given below:

The expression for the **Specific Gravity of Aggregates (G_{sb})** is given by

$$G_{sb} = \frac{M_{agg}}{V_{agg} + V_{air} + V_b}$$

M_{agg} = Mass of aggregates considered for the test;

V_{agg} = Measured volume of aggregates whose mass is considered above;

V_{air} = Volume of air voids present in the aggregates;

V_b = Volume of bitumen observed between the aggregates.

Apparent Specific Gravity is given by

$$G_{sb} = \frac{M_{agg}}{V_{agg}}$$

Theoretical **maximum specific gravity** of mix (G_{mm}) is given by

$$G_{mm} = \frac{M_{mix}}{(\text{Volume of mix} - \text{Volume of air voids})}$$

The expression for the **Effective Specific Gravity of Aggregates (G_{se})** is given by

$$G_{se} = \frac{M_{agg}}{V_{agg} + V_{air}}$$

$$\text{Also, } G_{se} = \frac{(M_{mix} - M_b)}{\left(\frac{M_{mix}}{G_{mm}} - \frac{M_b}{G_b}\right)}$$

M_b = Mass of bitumen used in the mix;

G_b = Specific Gravity of Bitumen

The **Air Voids** can be calculated by

$$V_a = \left(1 - \frac{G_{mb}}{G_{mm}}\right) \times 100$$

The presence of **voids in the mineral aggregates (V_{ma})** is given by

$$V_{ma} = \left(1 - \frac{G_{mb}}{G_{mm}} \times P_s\right) \times 100$$

P_s represents % aggregate present of total mass of mix

Volume of **Voids filled with bitumen (V_{FB})** can be expressed by

$$V_{FB} = \frac{V_{ma} - V_a}{V_{ma}} \times 100$$

4.1 IMPACTS OF COAL ASH (IN THE FORM OF BOTTOM ASH AND FLY ASH) ON DBM MIXES

At the preliminary stage of test, the fly ash and bottom ash have been used as replacement of

fine aggregates in the DBM mixes. For this present experimental work, the total content of coal ash is considered to be around 34 – 35 % of total mix by weight, and from this content, the percentage content of fly ashes in the form of mineral filler is certainly fixed or pre-determined i.e. 4.5 – 5 % by weight of the total mix. The quantity of the bottom ashes may be varied and which is done as per the gradations of the dense bound macadam design mix from MORTH specifications.

4.2 IMPACTS OF COAL ASH AND SISAL FIBER (IN THE FORM OF FLY ASH AND BOTTOM ASH) ON DBM MIXES

It is being observed that the alone coal ash is not able to deliver the satisfactory results for the

characteristics as per Marshall Method of bituminous design mix. The flow value and stability value does not lie under the specifications for the bituminous design mix. Moreover, the analysis in terms of density, air voids, voids in the mineral aggregates and voids filled with the bitumen is really at a back step when compared to the conventional design mix. Hence, characteristics of bituminous designed mix as per the Marshall Method are to be determined by the use of sisal fibers and coal ashes. The fiber content of the coal ash is about 14.5 % and its variation takes place from 0 to 1 % having increment of about 0.25 % with length of fiber as 20, 15, 10 and 5 mm.

Table 5.1: Analysis of Marshall Characteristics

Fiber content, %	Fiber length, mm	OBC, %	Optimum stability, kN	Flow value, mm	VA, %	VMA, %	VFB, %	G _{mb}
0.25	0	5.60	11.40	3.15	2.40	15.30	84.00	2.33
	5	5.70	14.20	4.00	3.60	16.70	79.00	2.28
	10	5.78	13.20	3.50	3.60	17.00	76.00	2.28
	15	5.87	12.80	3.80	3.10	16.60	80.00	2.27
	20	5.73	11.90	3.80	4.00	17.00	77.00	2.27
Fiber content, %	Fiber length, mm	OBC, %	Optimum stability, kN	Flow value, mm	VA, %	VMA, %	VFB, %	G _{mb}
0.5	0	5.60	11.40	3.15	2.40	15.30	84.00	2.33
	5	5.57	13.80	3.85	2.90	17.10	75.00	2.26
	10	5.60	15.00	3.50	2.80	15.80	82.00	2.30
	15	5.80	11.50	3.60	4.30	17.60	76.00	2.25
	20	6.13	12.00	4.90	4.00	17.90	78.00	2.24
Fiber content, %	Fiber length, mm	OBC, %	Optimum stability, kN	Flow value, mm	VA, %	VMA, %	VFB, %	G _{mb}
0.75	0	5.60	11.40	3.15	2.40	15.30	84.00	2.33
	5	5.90	12.20	3.70	3.60	17.30	80.00	2.26
	10	5.77	13.30	3.10	2.20	15.90	86.00	2.30
	15	6.00	12.50	3.40	4.00	17.90	78.00	2.25
	20	6.13	12.30	3.50	4.30	18.35	77.00	2.24
Fiber content, %	Fiber length, mm	OBC, %	Optimum stability, kN	Flow value, mm	VA, %	VMA, %	VFB, %	G _{mb}
	0	5.60	11.40	3.15	2.40	15.30	84.00	2.33

1	5	5.93	12.30	4.20	3.70	17.60	80.00	2.24
	10	5.77	12.50	3.40	4.40	17.65	76.00	2.24
	15	5.55	13.40	3.20	2.90	16.10	82.00	2.28
	20	5.63	12.65	3.8	2.40	16.20	83.00	2.28

V. CONCLUSION

The experimental approach to the present research work draws the following conclusions:

1. The Marshall tests concludes that Dense Bituminous Macadam designed mixes are formed by the addition of fly ash particles passing through 0.075 microns and bottom ash particles that lies in the range of 0.075 mm to 300 mm. These mixes are found to be the best design mixes that fulfills the criteria as per the Marshall tests such that the bituminous concentration, length of fibers and their concentration used are 5.7%, 10 mm and 0.51% respectively.
2. It is interesting to note that the flow values and values of Marshall Stability obtained falls under the acceptable range of criteria provided that the content of coal ash remains within 15 % range.
3. It is noted that the flow value of the mixes gets reduced drastically with rise in the length of fiber and its content along with the concentration of air voids. In contrast to this, the increase in the value of Marshall Quotient takes place which results into the increase in stability value of the mixes.
4. It is also concluded that the requirements for the optimum content of bitumen and emulsions to be used for the fiber coating increases with rise of length of fibers and its content.

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